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ASD-TR-90-5010

KC-135 GROUND COLLISION AVOIDANCE SYSTEM QUESTIONNAIRE

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Crew Station Evaluation Facility
Crew Systems Division
ASD/ENEC

AUGUST 1990

Final Report for the Period December 1989 through April 1990

DCS FOR INTEGRATED ENGINEERING AND TECHNICAL MANAGEMENT
AERONAUTICAL SYSTEMS DIVISION
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FOR THE COMMANDER

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Unclassified
SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) ASD-TR-90-5010	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION Crew Station Evaluation Facility	6b. OFFICE SYMBOL *(If applicable)* ASD/ENECH
7a. NAME OF MONITORING ORGANIZATION	
6c. ADDRESS *(City, State, and ZIP Code)* Wright-Patterson AFB, Oh 45433-6503	7b. ADDRESS *(City, State, and ZIP Code)*
8a. NAME OF FUNDING/SPONSORING ORGANIZATION ASD/SDB	8b. OFFICE SYMBOL *(If applicable)*
9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER	
8c. ADDRESS *(City, State, and ZIP Code)* Wright-Patterson AFB, OH 45433-6503	10. SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO	WORK UNIT ACCESSION NO.

11. TITLE *(Include Security Classification)*
KC-135 Ground Collision Avoidance System Questionnaire

12. PERSONAL AUTHOR(S)
Rueb, Justin D., Major, USAF; Hassoun, John A.

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT *(Year, Month, Day)*	15. PAGE COUNT
Final	FROM Dec 89 TO Mar 90	1990, August	

16. SUPPLEMENTARY NOTATION

17. COSATI CODES		
FIELD	GROUP	SUB-GROUP

18. SUBJECT TERMS *(Continue on reverse if necessary and identify by block number)*
Ground Collision Avoidance System (GCAS)
Ground Proximity Warning System (GPWS)

19. ABSTRACT *(Continue on reverse if necessary and identify by block number)*
In support of the Tanker System Program Office (SPO), the Crew Station Evaluation Facility engineers collected subjective data from a sample of 82 operational Strategic Air Command crew members. The data provide government and contractor personnel with information needed in the design of the Ground Collision Avoidance System (GCAS) for all KC-135 aircraft. The GCAS is designed to alert aircrews of an impending ground impact, should current flight conditions/aircraft configuration remain unchanged. This study found that KC-135 aircrews would prefer a multi-faceted, bimodal GCAS warning system. This should consist of a light/tone or light/voice warning. The light nomenclature, "altitude," and the voice message, "pullup" were the most preferred warning messages. The GCAS warning should be present for as long as the warning conditions exist or until the pilot activates a GCAS system reset switch. The GCAS should begin coverage from 200 feet (AGL) and remain active until 5000 feet (AGL). It should cover roll angles from zero degrees to a minimum upper limit of 45 degrees. Subject data and comments are discussed in further detail.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION Unclassified
22a. NAME OF RESPONSIBLE INDIVIDUAL Justin D. Rueb, Major, USAF	22b. TELEPHONE *(Include Area Code)* 513-255-4258
22c. OFFICE SYMBOL ASD/ENEC	

DD Form 1473, JUN 86 — *Previous editions are obsolete.*

SECURITY CLASSIFICATION OF THIS PAGE
Unclassified

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Introduction

With continued emphasis on defense budget cuts and manpower reductions, the United States Air Force must further minimize the potential risks to life and equipment inherent in the operational flying world. A recent review of all cargo/transport/tanker Controlled Flight Into Terrain (CFIT) mishaps covering the period of 1970-Present (Rueb & Kinzig, 1989) revealed that 18 of 31 (58%) mishaps may have been avoided had an operable GCAS system been installed. This would have saved numerous lives and millions of dollars. Accordingly, Strategic Air Command (SAC) has proposed the inclusion of an operable Ground Collision Avoidance System into its tanker aircraft as one possible solution to the CFIT problem.

Since current military standards do not provide specific directions for the design of a GCAS system, the Tanker System Program Office (ASD/SDB) requested Crew Station Evaluation Facility (CSEF) assistance in determining a set of specifications for a GCAS system with consideration given to user wants and needs. In response, the CSEF generated a GCAS user's questionnaire. This report describes the method used to obtain the data and then summarizes the results.

Method

Subjects

Eighty-two operational tanker crew members were surveyed. Participation was voluntary. Flying experience ranged from 330 to 5525 hours, with a mean of 1721 flying hours. The mean age of the respondents was 31.98 years with a span of 24 to 45.

Apparatus

The questionnaire, titled "Ground Collision Avoidance System for Cargo/Tanker Type Aircraft Questionnaire" (Appendix), was divided into six sections. The first was a personal data section used to determine the age and experience levels of the respondent sample. The general information section focused on the GCAS system as a whole. The next three sections focused on specific warning modes (visual, tone, or voice). The final section questioned the respondents about desired minimum recovery clearance altitudes. A detailed description of the results follows.

Procedure

The CSEF mailed 150 questionnaires to five operational SAC KC-135 tanker units at Altus AFB, Fairchild AFB, Grand Forks AFB, Malstrom AFB, and Robins AFB. The completed copies were returned to the CSEF within five weeks of the mailing date. Eighty two questionnaires were returned for a response rate of 55%. A data base was then generated based on subject responses. The data base is available upon request from the CSEF.

Survey Results and Discussion

The purpose of this questionnaire was to obtain user preferences regarding the proposed GCAS system for the tanker aircraft. Frequency data were compiled and presented in graph form to aid in the discussion of each question. Critical user comments and concerns were also discussed to provide a fuller understanding of desired GCAS user needs. For all of the figures in this report, the column labeled "Other" represents (1) respondents who chose an answer other than one that was listed and (2) respondents who failed to respond to the question.

Section I - Sample Demographics

With the stringent flying gate requirements and crew member initial training age restrictions (age < 27.5), the current age (mean=32, median=29) and rank distributions shown in Figures 1 and 2 are very representative of the current crew force. The crew position chart (Figure 3) indicates that the survey spans users from all crew positions and various flight experience levels, indicated by the representative numbers of copilots (CP), pilots (P), and instructor pilots (IP). Two of the eighty-two respondents were females.

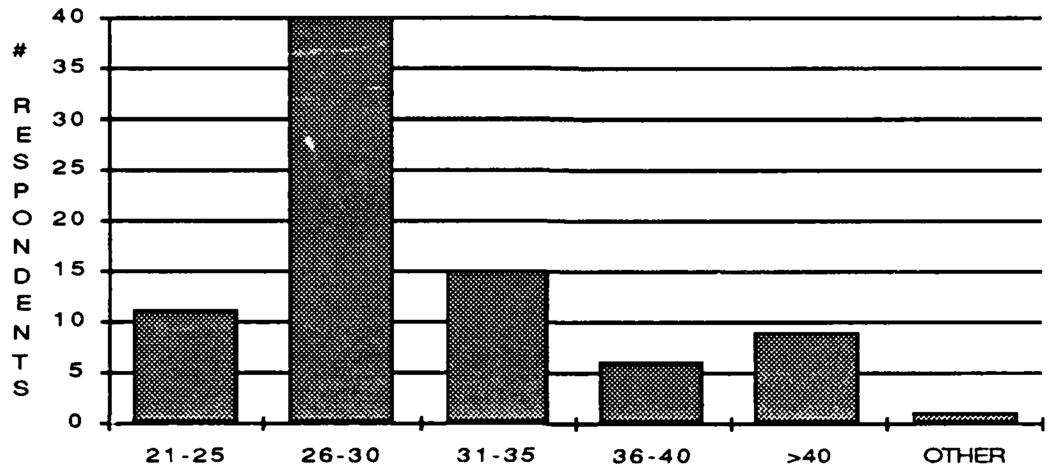

Figure 1. Age frequency distribution.

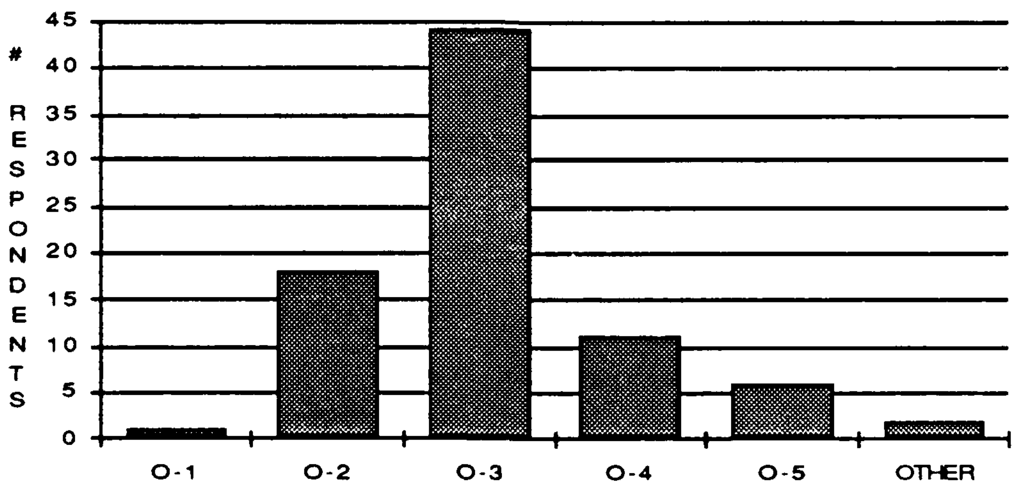

Figure 2. Rank frequency distribution.

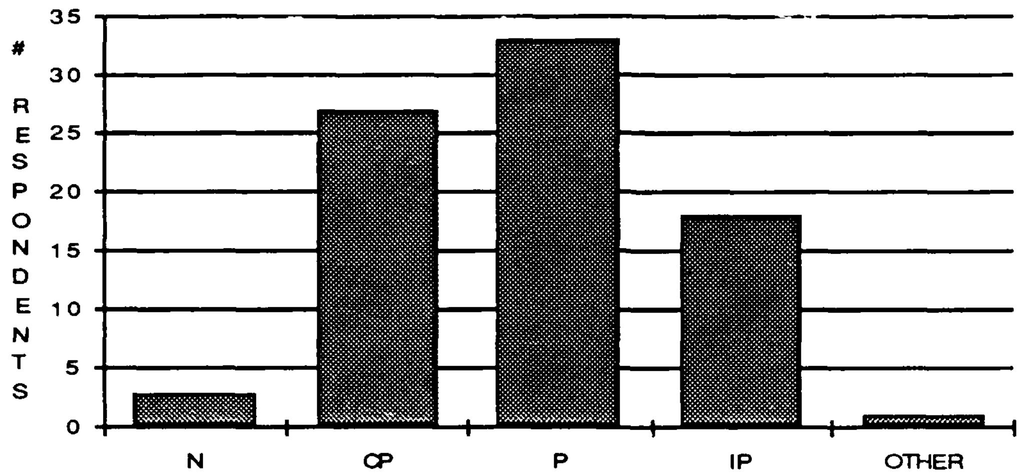

Figure 3. <u>Crew position frequency distribution.</u>

Figures 4-6 cover the various experience levels of the sample based on flight hours. Figure 4 represents the total flying hours each crew member had across all aircraft. The average flight total was 1720 hours with a median of 1450 hours. Figure 5 represents the total flying hours each crew member had in the KC-135 aircraft. The mean was 1190 with a median of 925 hours. A crew member's total flight time in his current crew position is reflected in Figure 6. The mean flight time was 615 with a median of 500 hours.

The means are consistently much larger than the medians. This apparent discrepancy is the result of the unusually high number of respondents (n=5) with total flight hours greater than 4500 hours. With today's budget constraints, many airborne flight hours have been eliminated or converted to high technology simulation hours. The divergence of the mean and median is a direct result of this situation, since the crew members with flight hours greater than 4500 bias the mean toward a value higher than that of the median. Generally speaking, the obtained sample was representative of the current crew force composition. Consequently, the responses to the questionnaire should be representative of the current KC-135 crew force.

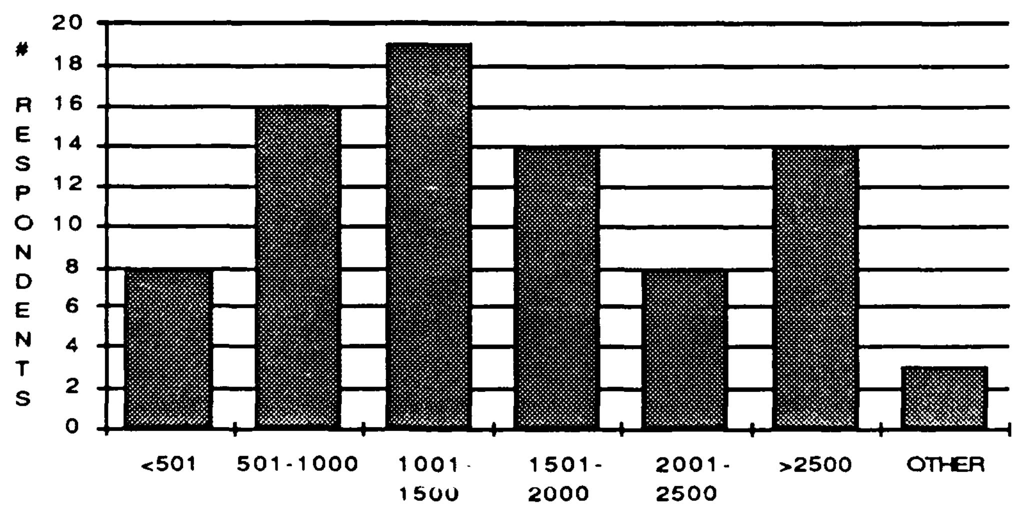

Figure 4. <u>Total flight hours frequency distribution.</u>

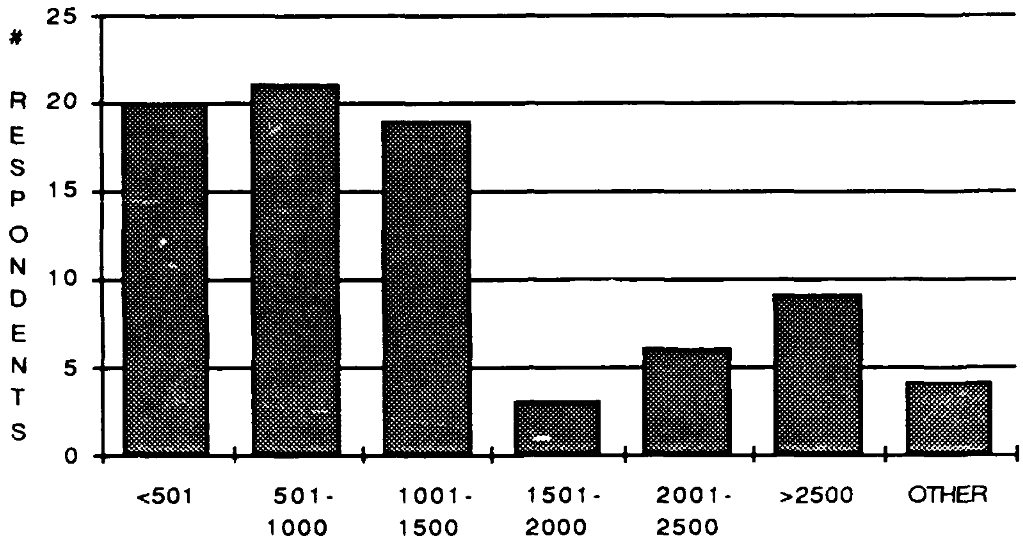

Figure 5. Total KC-135 flight hours frequency distribution.

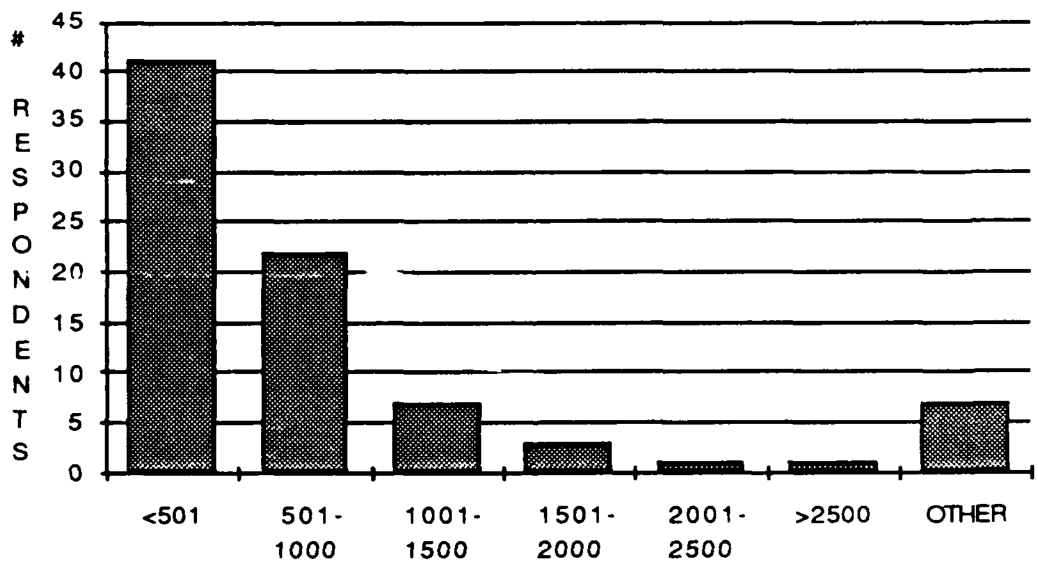

Figure 6. Total crew position flight hours distribution.

Section II - General Information

Is GCAS Beneficial? When posed this question, 58 of 82 subjects responded "yes, it is beneficial" (Figure 7). One subject commented that he could not answer the question (Other) because he was uncertain as to what a GCAS system is. Additionally, several respondents said yes given that proposed low level refueling for tankers becomes a reality. Several respondents also felt that a cost-effectiveness study should be run due to the age of the aircraft.

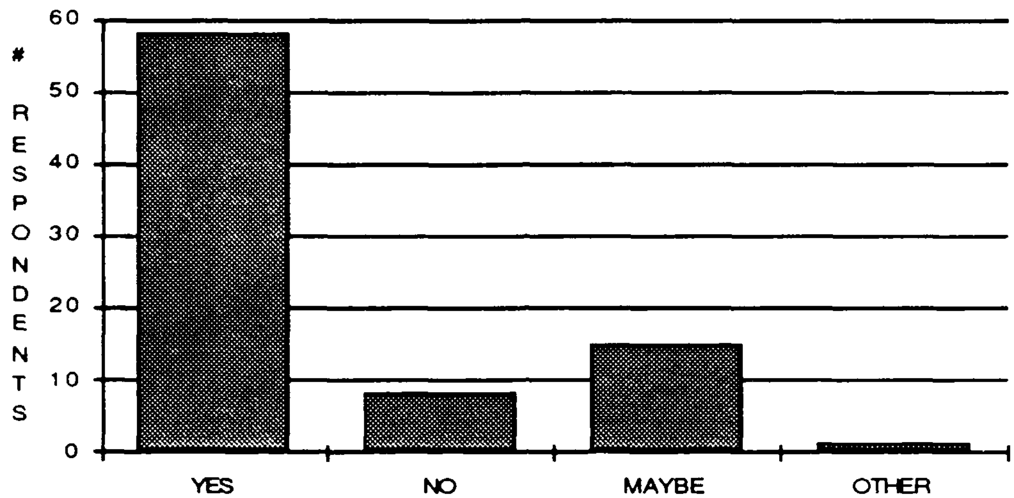

Figure 7. Is a GCAS system beneficial?

Preferred Sensory Modes. When asked "Which GCAS warning modes would be effective," none of the respondents felt that a light alone would be effective. Rather, the respondents felt that a combination of sensory modes would be most beneficial. Figure 8 indicates that a tone and light combination is slightly more preferable than the voice with light warning combination. Subjects stated that a light alone would be lost among the many other warning lights. Other comments suggested a voice warning could be too easily confused with other crew member's voices. Subjects also commented that the tone should be easily distinguishable from the other commonly used tones, such as the landing gear warning horn. This idea of modal redundancy (tone/voice with light) supported by these data were similarly reported by Werkowitz (1979).

Are Different GCAS Modes Beneficial? Most of the crew members fully believed that different GCAS modes would be beneficial (Figure 9). Only 4 of the 82 respondents answered no to this question. Several respondents commented that this feature must be automatic, requiring no pilot action to change modes, to be functional, otherwise, another flight procedure would have to be added to an already demanding environment.

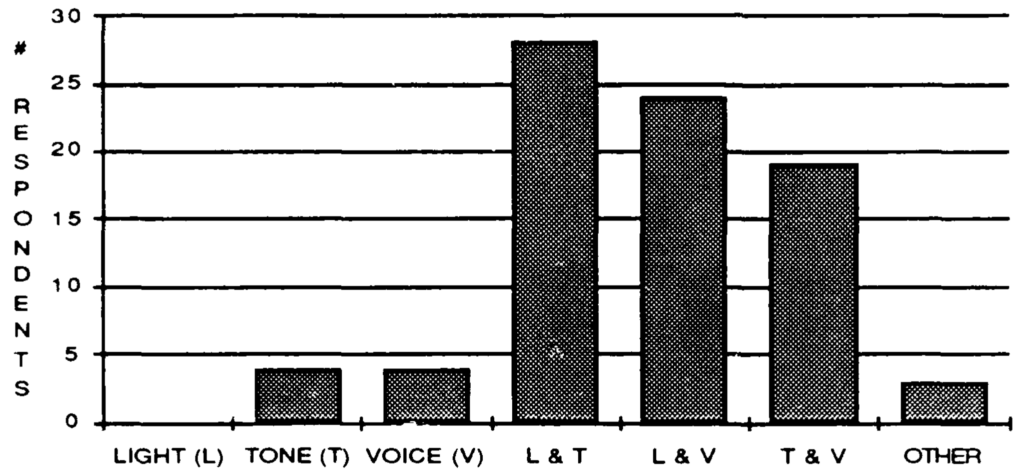

Figure 8. <u>Warning mode preference frequency distribution.</u>

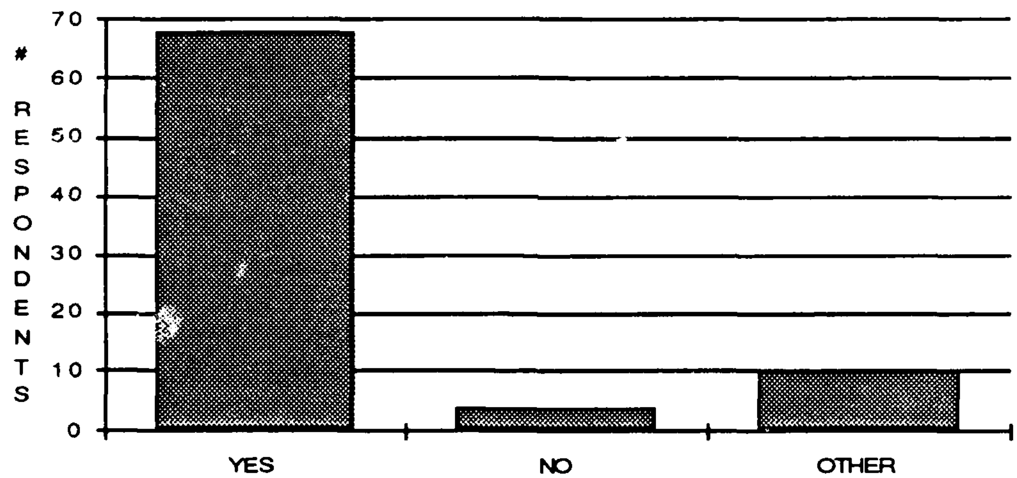

Figure 9. <u>Are different GCAS modes beneficial? frequency distribution.</u>

<u>Beneficial GCAS Modes Identified.</u> Question 4 required subjects to indicate whether they considered the listed modes (Approach & Landing, Low Level, Rapid Descent, Take off, and Wind Shear) as beneficial. Figure 10 suggests that Approach and Landing, and Wind Sheer were strongly perceived as beneficial; whereas, the remaining modes were considered beneficial by less than 50 percent of the respondents. This suggests crew members would prefer at least a two-mode system.

<u>Relative Ranking of the Various GCAS Modes.</u> Subjects were asked to rank order the above listed GCAS modes from most beneficial to least beneficial. Figure 11a presents the ranking preference for all respondents across all of the GCAS modes. Approach and Landing had a statistical mode of 1 with a median of 2, indicating that it was the GCAS mode considered as most beneficial. The Wind Sheer GCAS mode was considered the next most beneficial with a modal value of 2 and a median of 2. The

Takeoff, Rapid Descent, and Low Level GCAS modes; with statistical modes of 3, 4, and 5 and medians of 3, 4, and 4, respectively, were not seen as very beneficial. This parallels the findings in Question 4 above. Figures 11b-11f are magnified views of Figure 11a for each of the GCAS modes.

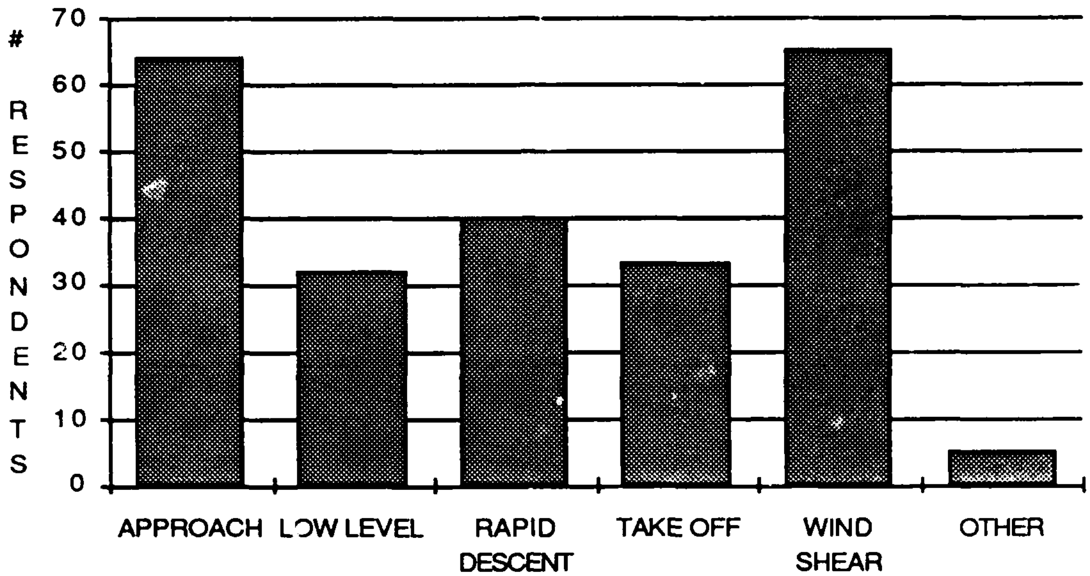

Figure 10. **Effectiveness of different GCAS modes frequency distribution.**

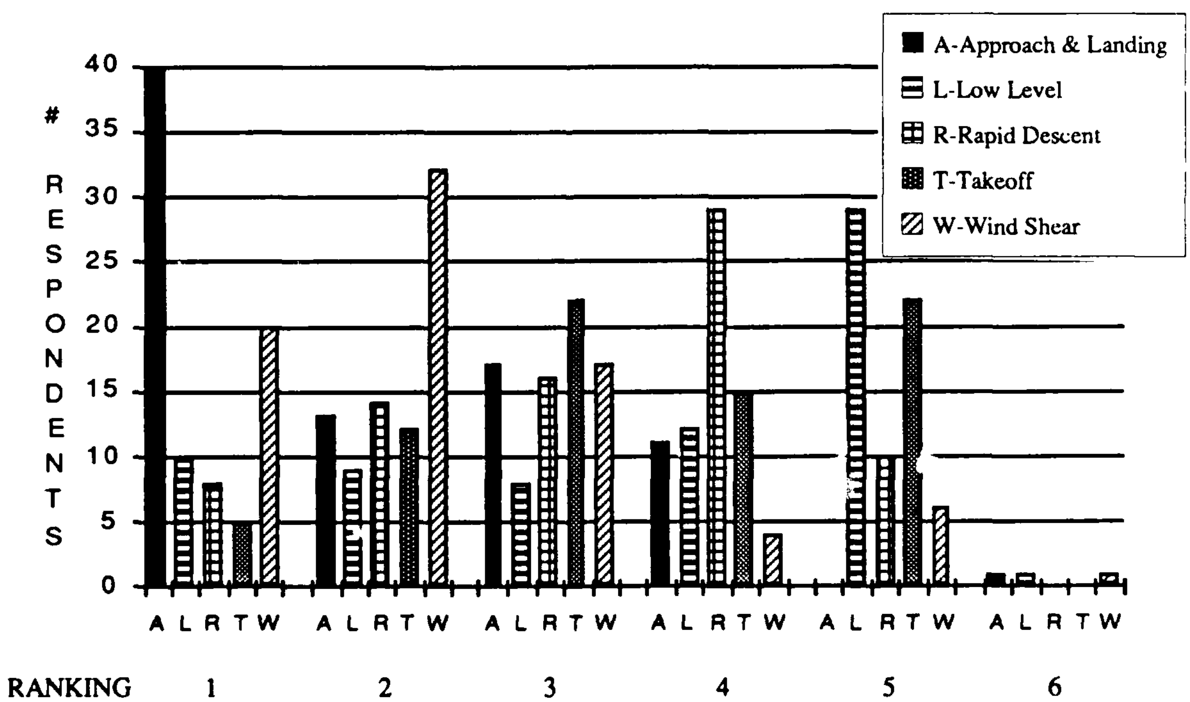

Figure 11a. **GCAS modes ranking distribution.**

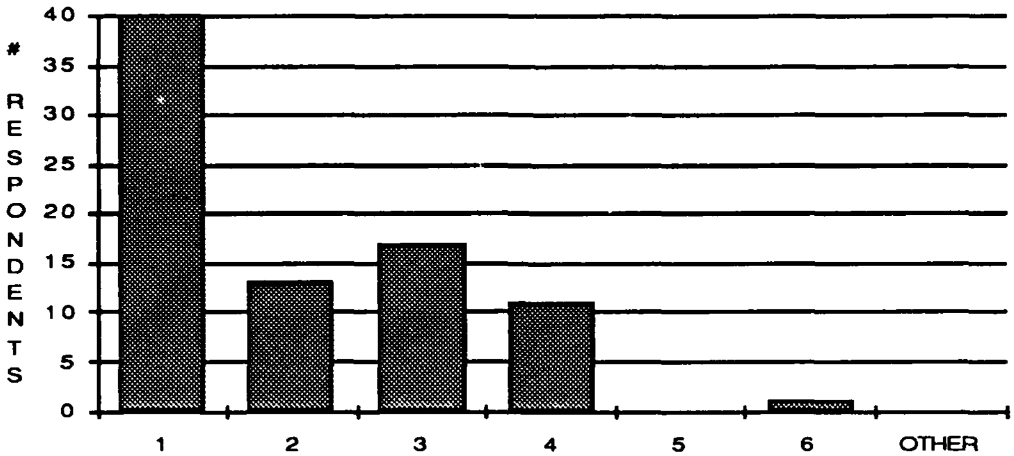

Figure 11b. Approach and landing mode ranking distribution.

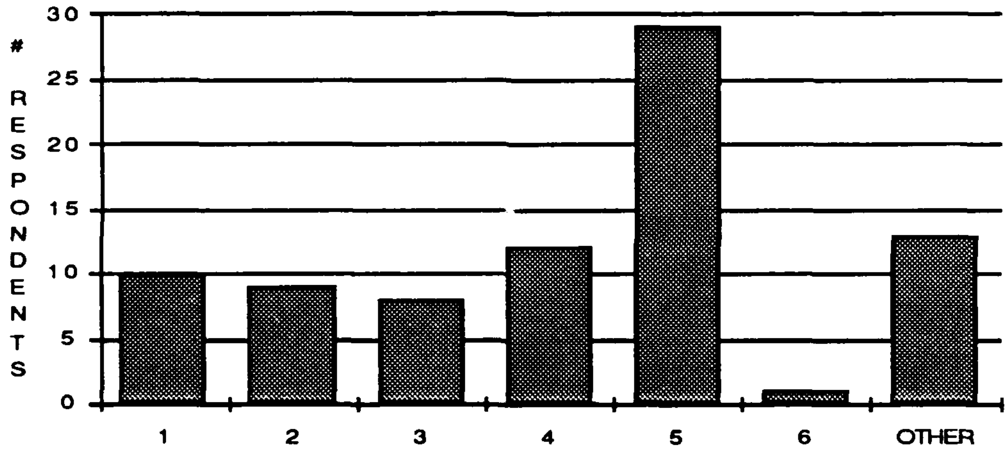

Figure 11c. Low level mode ranking distribution.

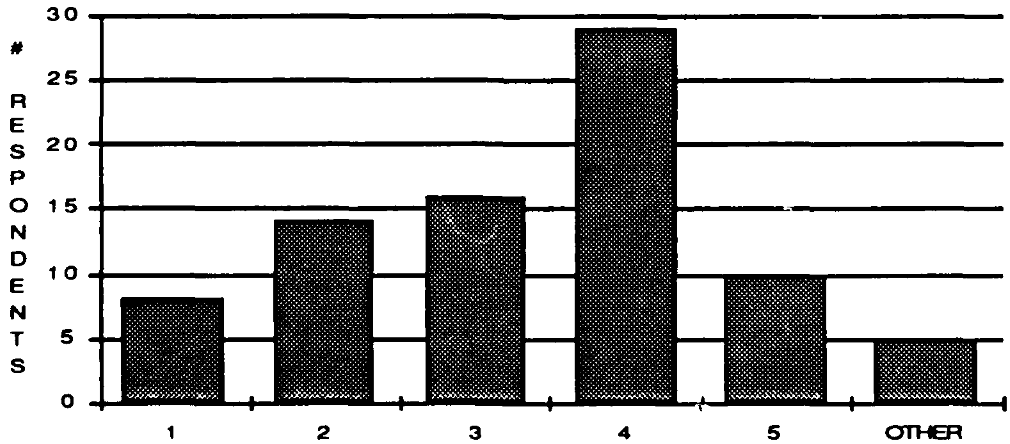

Figure 11d. Rapid Descent mode ranking distribution.

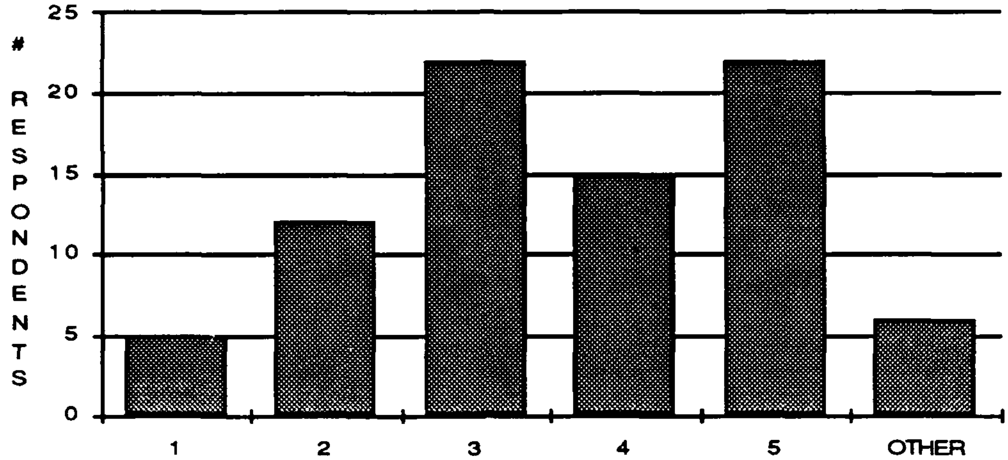

Figure 11e. Takeoff mode ranking distribution.

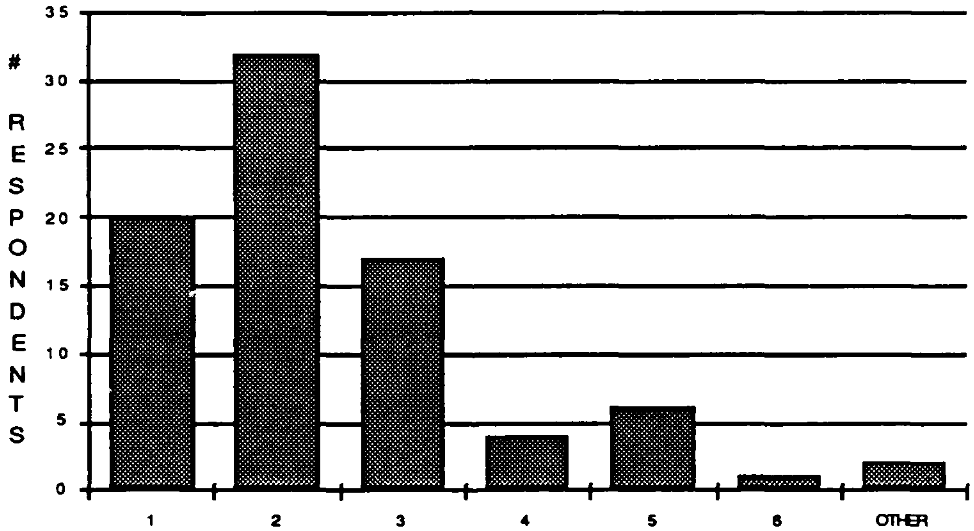

Figure 11f. Wind Shear mode ranking distribution.

Subject comments indicated that the ranking of the Low Level mode would drastically change if low level refueling became a reality for the KC-135 tanker. One subject emphasized that a mode (i.e., Approach & Landing) should cover the entire traffic pattern. Another respondent felt that a mode designed specifically for a high terrain environment would be very useful.

GCAS Manual Shutoff? 60 of 82 respondents answered yes when asked if the pilot should be able to turn off the GCAS (Figure 12). Malfunctioning of the GCAS and silencing of a nuisance warning were the two reasons most frequently noted. Several respondents felt that a reset switch that disengages the warning until conditions worsen would be appropriate.

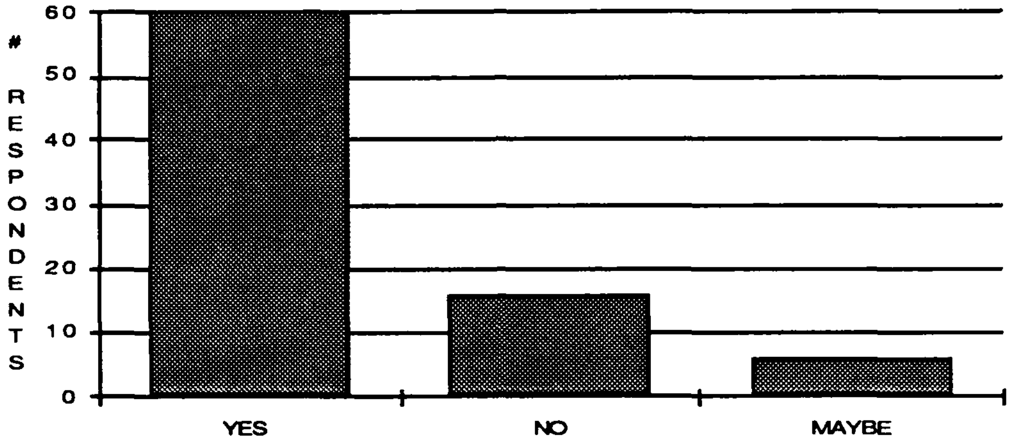

Figure 12. GCAS manual shutoff preference frequency distribution.

Pitch limits. Question 7, What should the pitch limits of the GCAS be?, was not analyzed due to the ambiguity of the question. No explanation of minimum and maximum pitch and no instructions for the proper coding of the answers were provided in the question. Researchers were uncertain whether a given response of five degrees for a minimum meant five degrees nose up or five degrees nose down. Additionally, some subjects used plus and minus signs interchangeably causing additional confusion as to which sign represented nose up or nose down.

Roll Limits. Figures 13a and 13b show the distribution of responses for the minimum and maximum roll limits of the GCAS, respectively. Twenty-eight of the respondents felt the minimum GCAS limit should be zero. The average minimum roll limit was 9 degrees with a median of 0 degrees. The distribution for the maximum GCAS roll limit centers around 45 degrees. The average maximum GCAS roll limit was 47 with a median of 45. Although 50 percent of all subjects failed to respond, the consistency of the responses strongly indicates that the roll limit coverage should be from 0 to 45 degrees. This finding must be qualified since some confusion was noted among the respondent's answers.

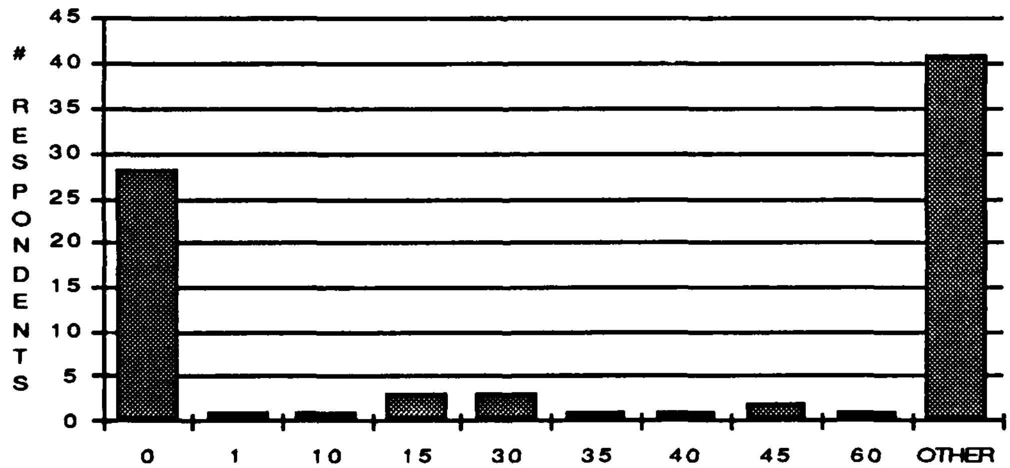

Figure 13a. Minimum GCAS roll limit distribution.

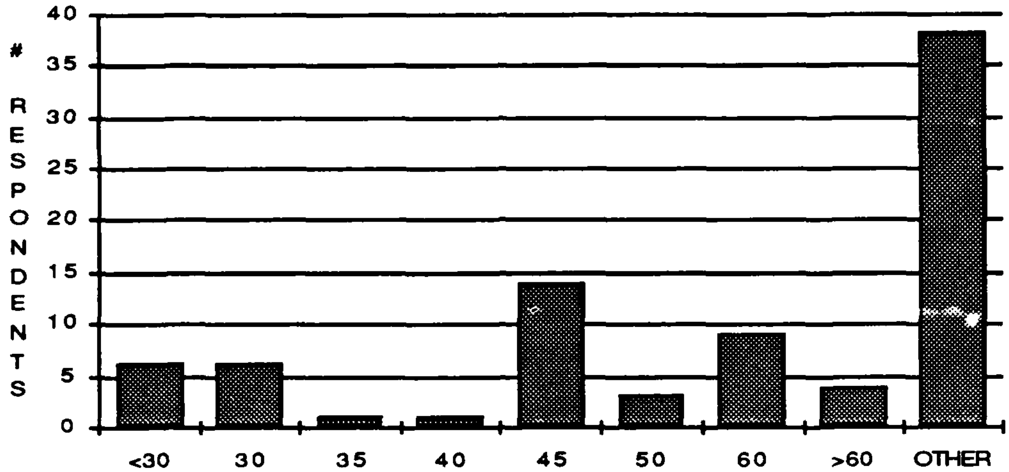

Figure 13b. Maximum GCAS roll limit distribution.

Radar Altimeter Extrapolation. Forty-six subjects indicated the system should be capable of extrapolation beyond the range of the radar altimeter and during periods of questionable radar altimeter inputs (Figure 14). Additionally, many commented that extrapolation would be extremely useful in situations where a rapid descent rate was involved. Three respondents expressed concerns for the reliability of the current radar altimeter due to its age.

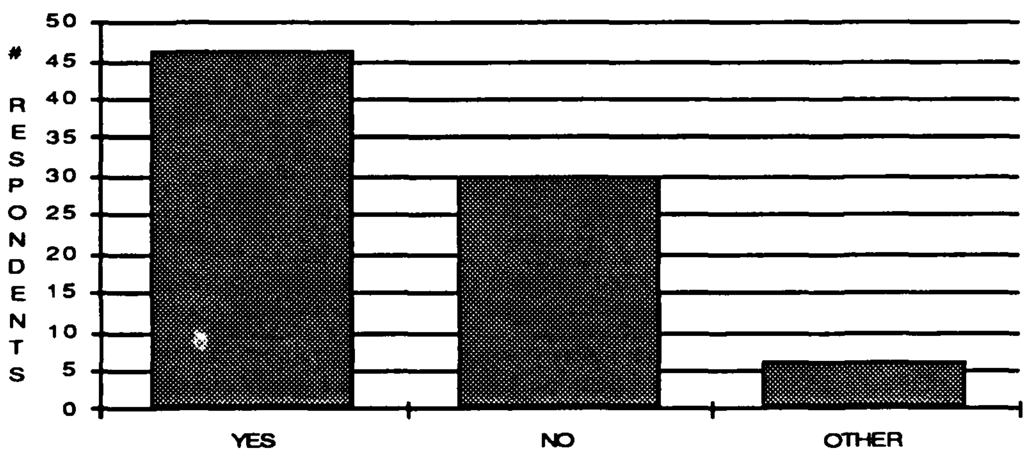

Figure 14. Radar altimeter extrapolation preference distribution.

GCAS Maximum Altitude Coverage. When asked what the maximum altitude at which a GCAS system should operate, subjects were almost evenly split between 5000 feet and the maximum coverage of the radar altimeter (Figure 15). This is understandable since the large majority of radar altimeters in the Air Force inventory have a maximum coverage of 5000. In essence, these answers are repetitive. Several respondents suggested the maximum and minimum altitude coverage should be pilot adjustable.

Minimum Descent Altitude. The largest percentage of subjects chose 200 feet as the minimum altitude (Figure 16). This is not at all surprising since most precision approaches have a decision height of 200 feet. Furthermore, subject comments suggest the minimum coverage altitude should be adjustable to correspond with the minimum descent altitude/decision height for the approach.

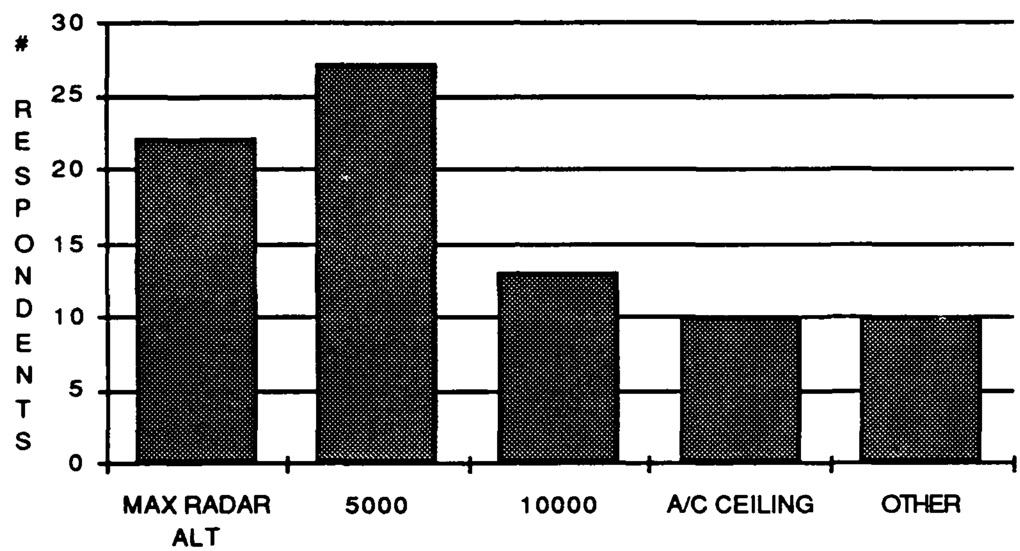

Figure 15. GCAS maximum altitude coverage frequency distribution.

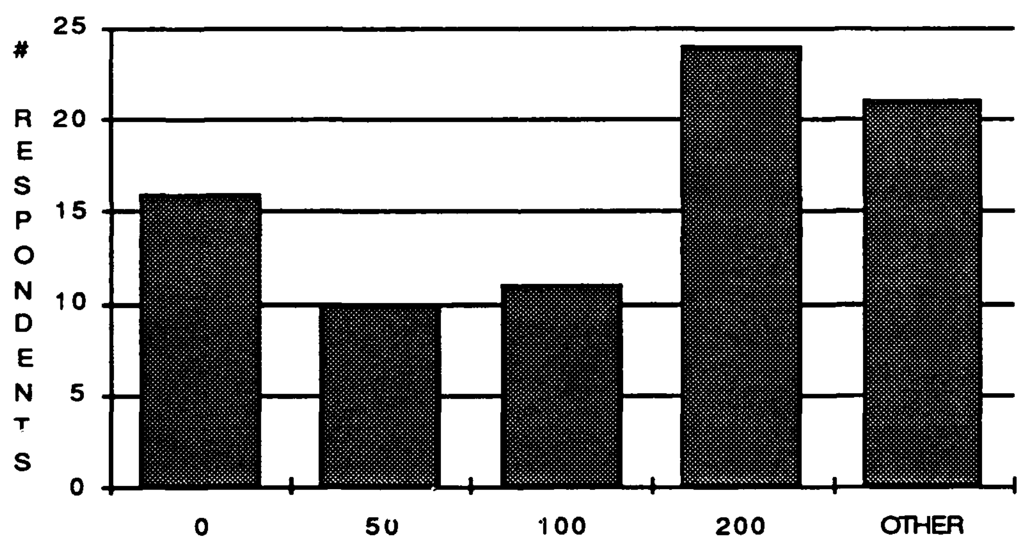

Figure 16. GCAS minimum altitude coverage frequency distribution.

Section III - Visual Information

<u>Type of Warning Light.</u> Without question, the subjects (77 of 82) preferred a flashing light over a steady light (Figure 17). However, as noted earlier, subjects also felt strongly that the light must be accompanied by some other warning signal.

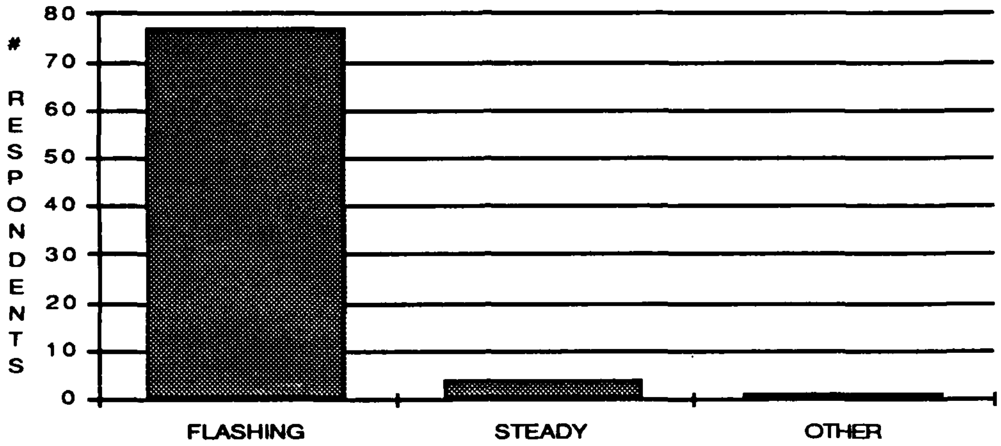

Figure 17. <u>Preferred type of warning light frequency distribution.</u>

<u>Warning Light Nomenclature.</u> The word "Altitude" was preferred by 23 of the 82 respondents (Figure 18). "Pull up" was second with 15 responses. The remaining three choices were equally preferred with 11 responses each. Subject comments mirrored these results.

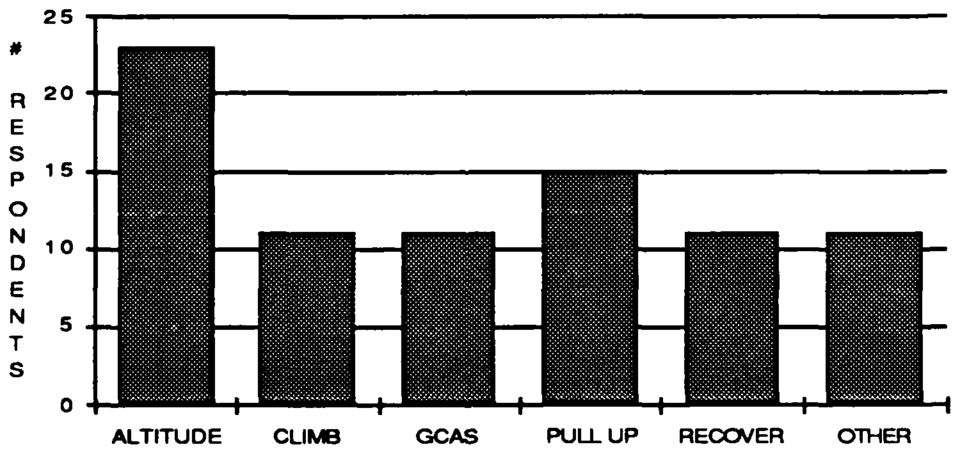

Figure 18. <u>Preferred warning light nomenclature frequency distribution.</u>

<u>Warning Light Duration.</u> Figure 19 clearly indicates the warning light should remain on for as long as the warning condition exists. Eleven comments were given. Each comment indicated the need for some type of pilot GCAS cutoff/reset capability. Subjects felt a reset capability that silenced the warning indication until conditions worsen would enhance the system's usefulness.

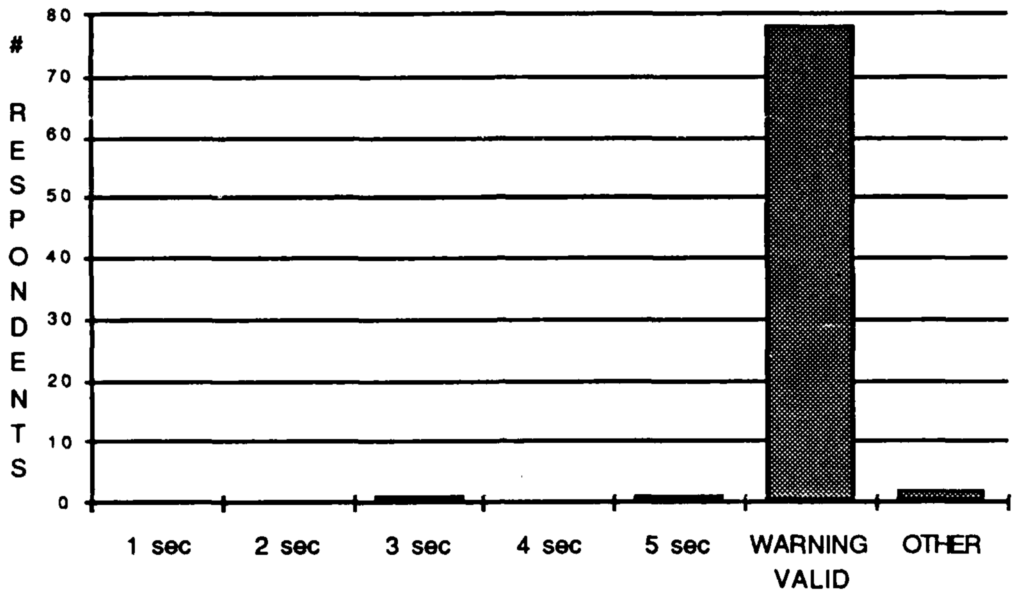

Figure 19. <u>Preferred warning light duration frequency distribution.</u>

<u>Time Interval.</u> The majority of all respondents chose 0.5 second as the optimal interval between light flashes (Figure 20). This agrees completely with the research finding of Hassoun, Barnaba, and Matheson (1988).

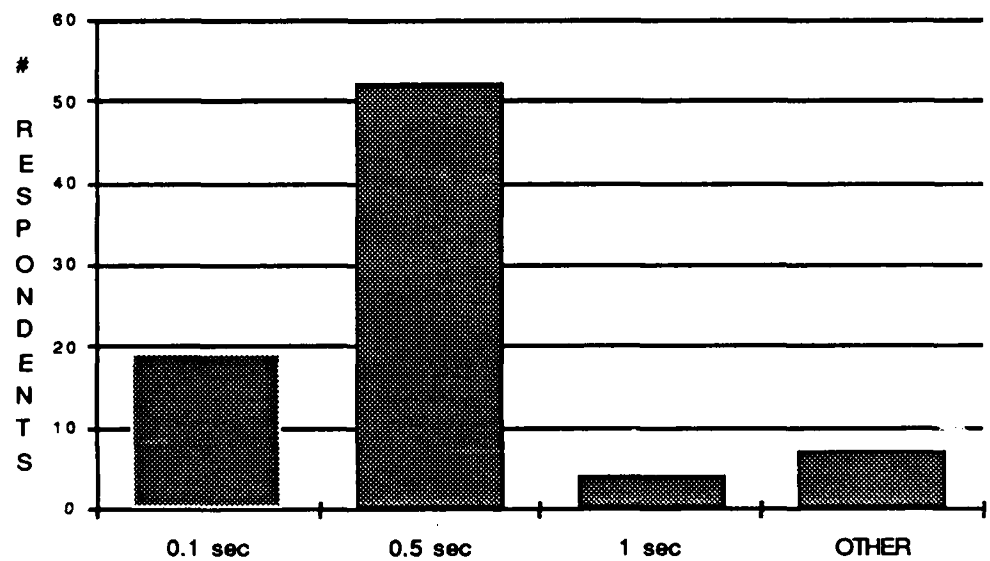

Figure 20. <u>Preferred warning light time interval frequency distribution.</u>

Section IV - Tone Information

Type of Warning Tone. The results indicate that a steady tone would be of little value (Figure 21). Subjects commented that a steady tone would be too easily confused with tones already present in the cockpit. They also felt it would be much easier to ignore a steady tone. A tone that increases in frequency or pitch as the condition worsens was one subject's recommendation.

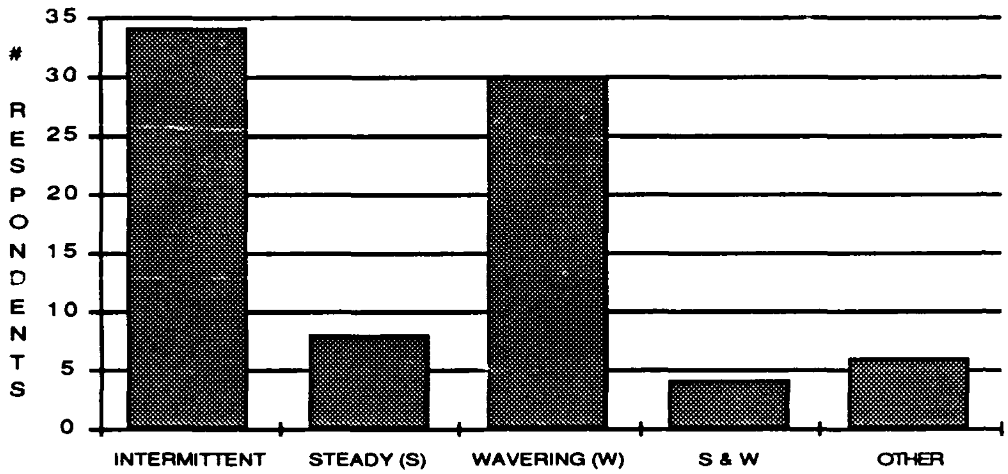

Figure 21. Preferred type of warning tone frequency distribution.

Tone Warning Duration. Respondents answered this question (Figure 22) in the same definitive manner as the warning light duration question earlier (Figure 19). Seventy-one of the eighty-two subjects felt the warning should be present for as long as the warning condition existed. In a similar fashion, comments were directed toward the installation of a pilot reset switch that silences the horn until conditions worsen.

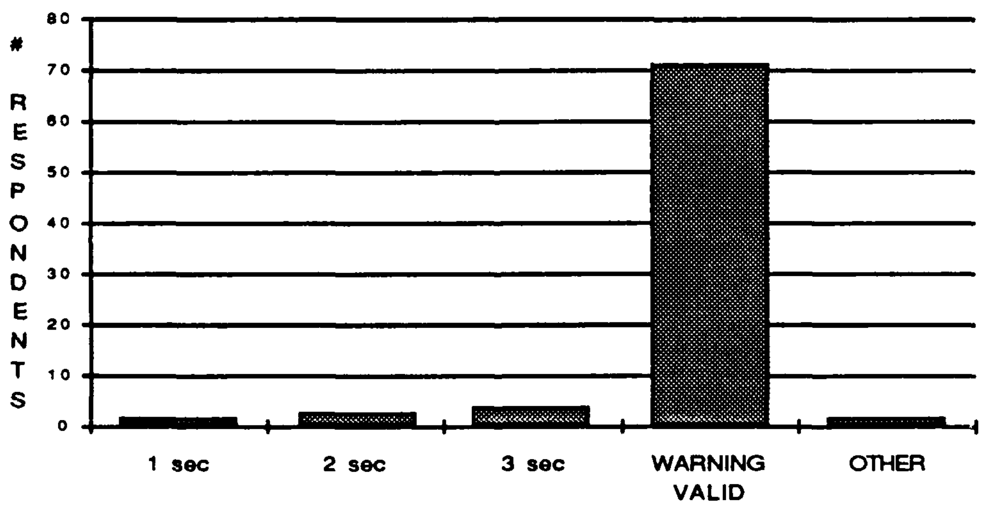

Figure 22. Preferred warning tone duration frequency distribution.

Tone Warning Interval. The preferred optimal interval between tones was 0.5 second (Figure 23). Again, this parallels the Hassoun et al. (1988) findings.

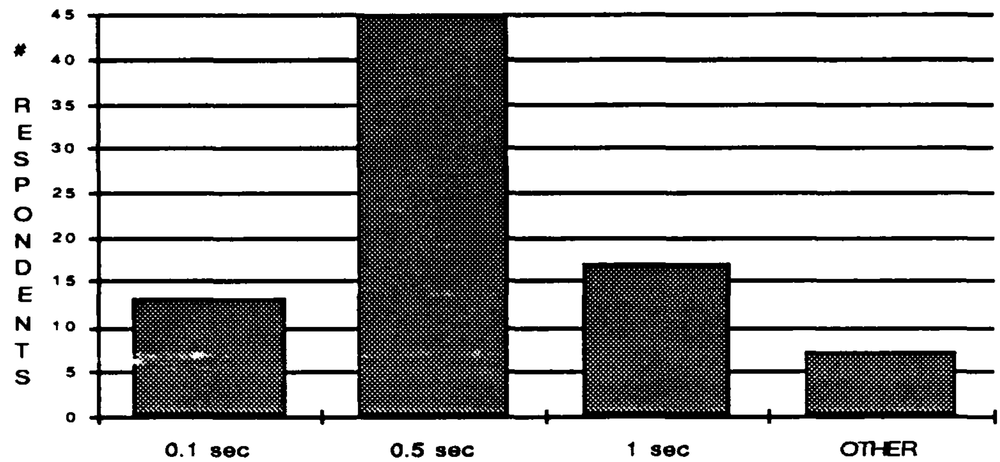

Figure 23. Preferred time interval between tones frequency distribution.

Section V - Voice Information

Type of Voice Warning. Human female was the most preferred form of voice warning (Figure 24). However, several respondents felt another voice would simply cause more confusion within the cockpit. Given a voice must be used, then the voice should be highly distinguishable. A case for a female voice could be made, since the majority of aerial communications involve male to male interfaces. Appropriately, the human female was the most preferred form of voice warning (Figure 24). Hassoun et al. (1988) also reported that a female voice was the most preferred form of voice warning.

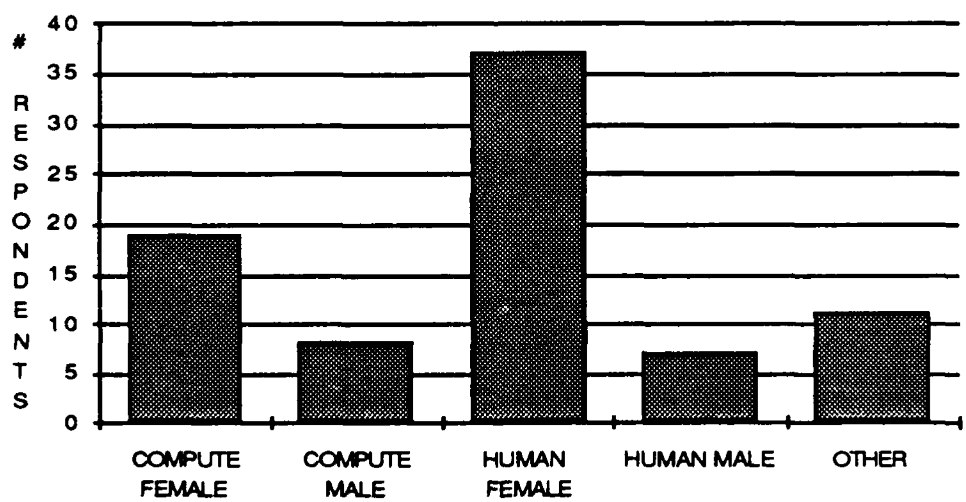

Figure 24. Preferred type of voice warning frequency distribution.

Type of Voice Message. As evidenced in Figure 25, "Pull Up" was the preferred voice message. Hassoun et al. (1988) had a similar finding. Altitude, which was the preferred nomenclature for a visual warning, was the next most preferred voice message. However, comments indicated that a generic response (altitude) might be more preferable than a specific response (pull up) because "pull up" may be an incorrect first response. The specific initial response should be the decision of the pilot. Further research should address this possibility.

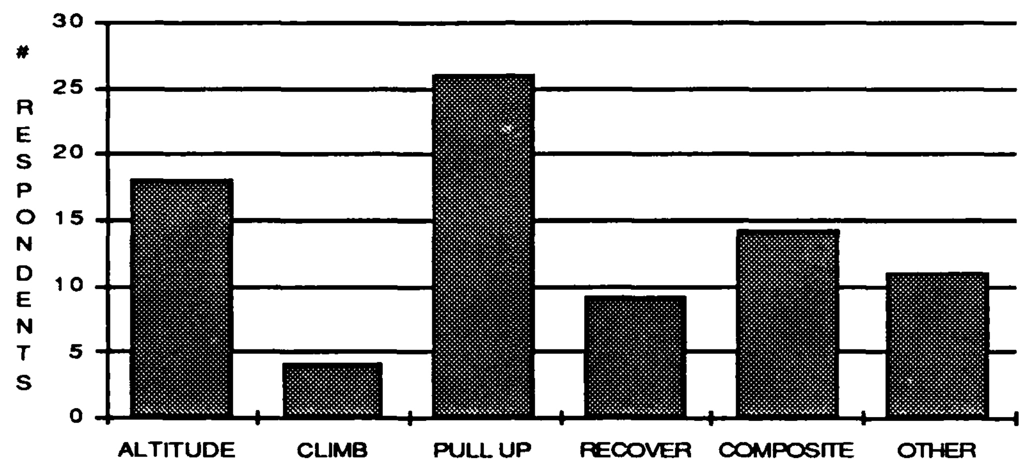

Figure 25. Preferred warning message frequency distribution.

Voice Message Repetitions. Figure 26 indicates respondents answered in a similar fashion as visual question 3 and tone question 2. The voice warning should be continuously presented until the warning condition no longer exists. The addition of a pilot cutoff/reset switch was strongly endorsed by the subjects. This type of switch should silence the warning signal until conditions worsen.

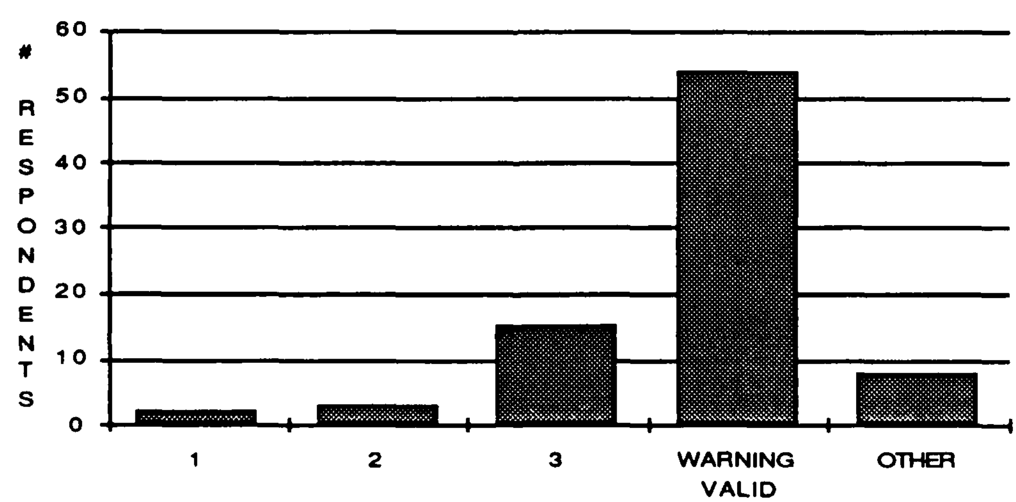

Figure 26. Preferred number of message repetitions frequency distribution.

Time Interval between Voice Messages. One-half of all respondents chose 1 second as the preferred interval between messages (Figure 27). One respondent suggested the frequency of the message should increase as the severity of situation worsens.

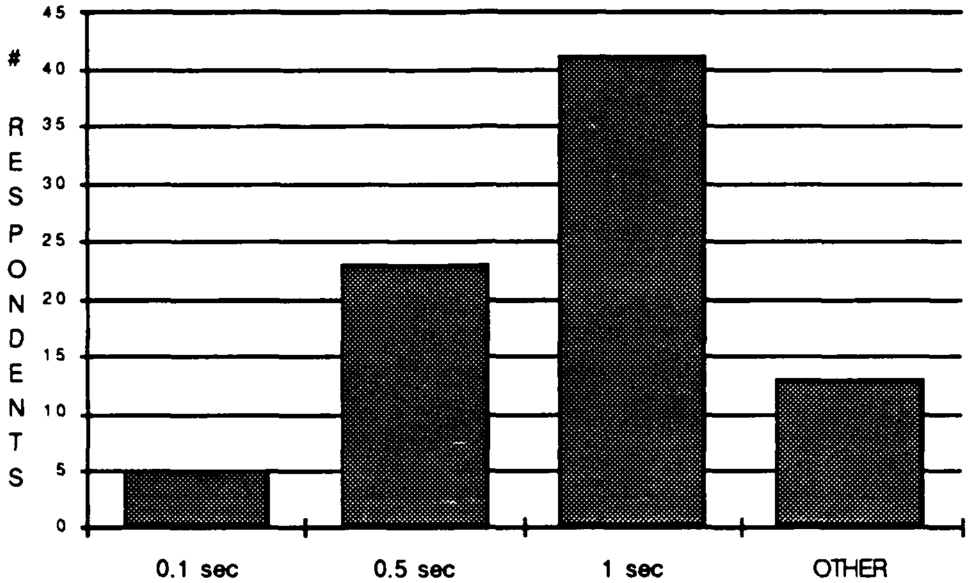

Figure 27. Preferred time interval between voice messages frequency distribution.

Section VI - Minimum Acceptable Clearance Altitude

The Minimum Acceptable Clearance Altitude (MACA) graph (Figure 28) represents the relationship between what a pilot feels is the minimum acceptable clearance altitude (Above Ground Level-AGL), given the aircraft's downward vertical velocity (Vz). MACA is the lowest altitude that an aircraft reaches during recovery from the initial GCAS warning for which a pilot feels minimum stress.

Subjects were first asked whether they fully understood the concept and how to plot it (Figure 29). Fifty-one respondents stated they fully understood the concept and could plot their subjective MACA curves/lines. An analysis of all the subject's plots indicated that the MACA concept was obviously misunderstood by three subjects since their plots were insufficiently drawn.

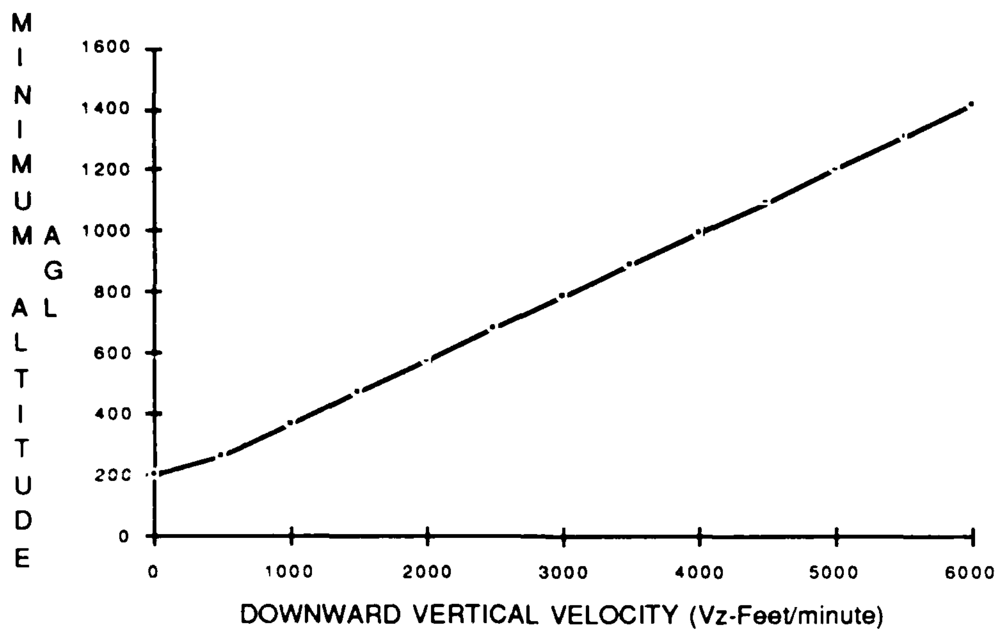

Figure 28. KC-135 MACA predicted window of acceptability (lower limit).

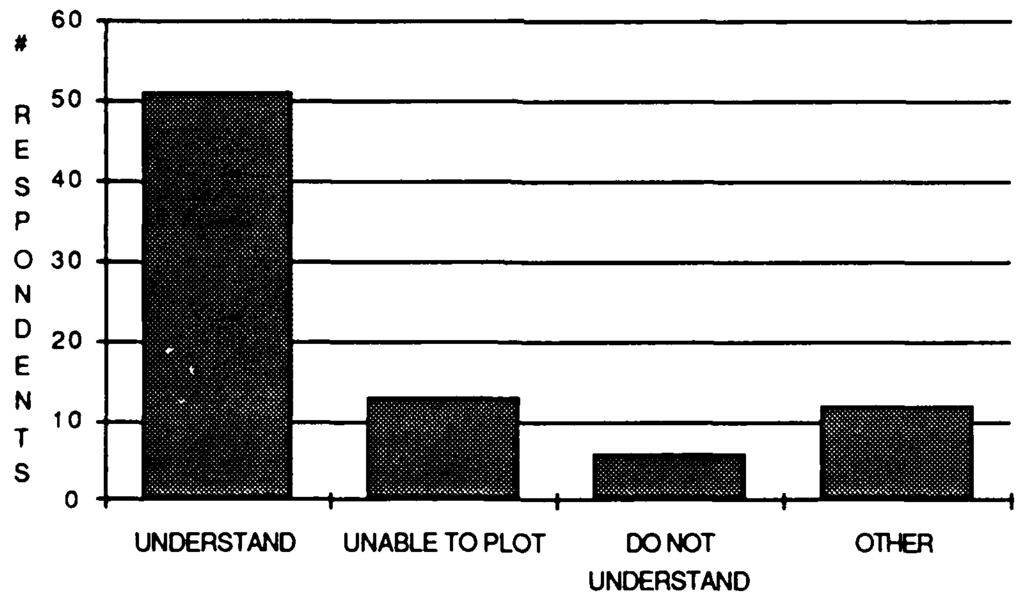

Figure 29. KC-135 MACA predicted window of acceptability (lower limit).

Data points extrapolated at 500-foot intervals from each subject's plotted graph were input into a database. This database was subjected to a linear regression with the resulting curve shown in Figure 28. The data were analyzed for possible polynomial relationships, but the data only supported the simple linear model. This line is of the form Y = 159 + 0.2088X and represents the collective opinion of the minimum acceptable clearance altitude given the various dive rates of the KC-135 aircraft. The intercept displayed by the graph, however, indicates the intercept as 200 feet. This is in agreement with question 11 from the general information section. This also occurs because at descent rates less than 500 fpm, pilots generally reported a constant altitude of approximately 200 feet as the minimum acceptable clearance altitude. This graph will be compared in a later phase of the study to the man-in-the-loop simulation clearance altitudes provided by the GCAS algorithm.

General Discussion

The overall results of this study were straightforward and paralleled the findings of Hassoun, Barnaba, & Matheson (1988) and Werkowitz (1980). It is interesting to note that differences did exist between tanker aircraft and fighter aircraft Minimum Acceptable Clearance Altitude graphs. A simple look at the axis of the graphs (Figures 28 & 30) indicates the immense differences between aircraft. The x-axis for the tanker aircraft is in thousands of feet per minute, whereas, the x-axis for the fighter aircraft is in hundreds of feet per second (tens of thousands of feet per minute). Specifically, tanker crew members desired significantly higher altitudes for clearance (Figure 28) than F-111 fighter personnel (Figure 30; Hassoun, Ward, Barnaba, & McCarthy, 1990). We attribute this to the increased maneuverability of the fighter-type aircraft. Additionally, fighters train and operate in higher speed, lower altitude environments than tanker aircraft, thereby, increasing their confidence, which in turn reduces their need for higher clearance altitudes.

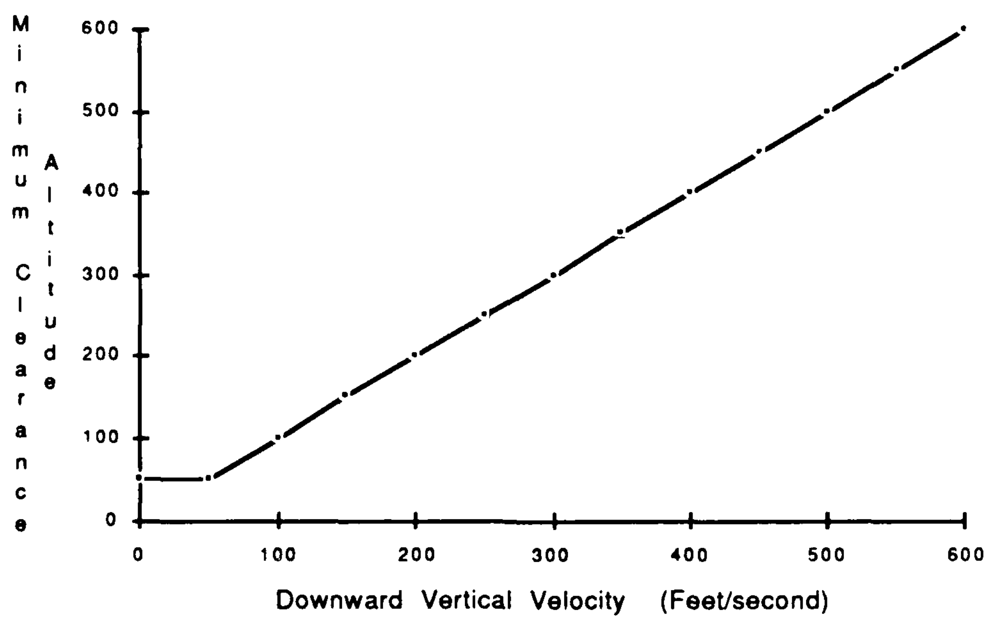

Figure 30. F-111 MACA window of acceptability (lower limit).

Another difference that appeared between our study and the Hassoun et al. (1988) study was the importance that the "altitude" voice message had. In the Hassoun et al. study subjects clearly indicated that "pull-up" was the most preferred voice message (65 of 120 responses). Respondents selected "altitude" only 19 times. Our study indicated that altitude was the most preferred wording for a visual signal and was second (18 of 82 responses) to "pull-up" (26 of 82 responses) as the most preferred voice message. The differences may be attributed to training differences. Since training in the tanker generally involves low to moderate dive and climb angles, the use of the term "pull-up" is often replaced with the more generic term of "altitude." As indicated by one respondent, a typical tanker crew member warning for an altitude deviation is "Altitude, climb/descend." Given this, it is not surprising to find that "altitude" yielded the results it did.

Recommendations

Based on the results of this questionnaire, we feel that a multi-faceted GCAS System should be used which, as a minimum, includes the Approach & Landing and the Wind Shear modes. This system should use a bimodal warning approach. This could be either a tone with light or a voice with light combination. The light should be a flashing light with the nomenclature "altitude" written on it. The tone should be a wavering tone that increases in frequency as the warning conditions worsen. It should be easily distinguishable from the other cockpit tones (e.g., landing gear warning horn). If a voice is chosen, a human female voice should be used to avoid confusion inside the cockpit.

The parameters of the GCAS should cover roll angles ranging from zero to a minimum of 45 degrees. The system should automatically activate at 200 feet (AGL) and provide coverage up to an altitude of 5000 feet (AGL). The actual warning signals should be present until the condition no longer exists or the pilot activates the reset switch. The reset switch should provide the pilots the capability to reset the system until conditions worsen. Should the system malfunction, circuit breakers placed within arm's reach of the pilots can act as the system's emergency on-off switch. This will avoid inadvertent shutoff of the GCAS, which is possible if a toggle switch had be used.

It is interesting to note that many of the above recommendations have been implemented by various GCAS systems on the market. Sundstran Data Control has its Mark VII system which is a multi-mode, multimodality warning system. The system also includes several inhibit and reset switch capabilities. Cubic Defense Systems Corporation is also currently developing a multi-mode system. To the extent possible, future systems should consider these findings and incorporate them. This report and its findings are empirically derived and should be used as a supplement to current Military Standards and Specifications (MIL-STD-1472D, MIL-STD-411D, MIL-STD-1776).

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Appendix

GROUND COLLISION AVOIDANCE SYSTEM (GCAS) QUESTIONNAIRE

This survey covers aspects of the Ground Collision Avoidance System (GCAS) that may be incorporated into the KC-135 aircraft as part of the new Avionics Modernization Program (AMP). Survey results will be used to support the design of the GCAS system currently proposed for the KC-135 aircraft. Your sincere cooperation in completing this survey will enhance aircrew acceptability of the GCAS system.

For each of the following questions, circle what you believe is the appropriate option. Answers are listed in alphabetical or numerical order without regard to actual importance. Each question has a comment section for you to include any relevant comments not considered by the question. This section will allow you to add any additional options/comments not previously listed. However, ensure you select one of the available options, before including any comments. Please use your personal judgement in responding to all the items covered throughout this survey. All surveys should be completed and returned to ASD/ENECH-CSDF, Wright-Patterson AFB, OH, 45433 by January 31, 1990.

PERSONAL DATA

Name (Optional):____

Rank:____

Aeronautical Rating:____

Organization:____

Office Symbol:____

Duty Station:____

Crew Position:____

Total Flying Hours:____

Total KC-135 Flying Hours:____

Total Hours Current Crew Position:____

Age:____________________ Sex:____________________

Describe any prior experience with Ground Collision Avoidance Systems (GCAS) or Ground Proximity Warning System(GPWS): ____________________

GENERAL INFORMATION

1. Would you consider a Ground Collision Avoidance System (GCAS) to be beneficial for warning an aircrew of a possible ground collision?

(a) Yes
(b) No
(c) Maybe (Please explain in comments)

Comment(s):____

2. Which of the following GCAS warning modes would you consider as most effective in attracting an aircrew member's attention in a cockpit environment?

(a) Light
(b) Tone
(c) Voice
(d) A combination of light and tone
(e) A combination of light and voice
(f) A combination of tone and voice
(g) Other (Please specify)

Comment(s):____

3. Would you consider different GCAS modes (e.g. low level, takeoff, wind shear, etc.) that adjust for the different phases of flight as beneficial?

(a) Yes
(b) No
(c) Maybe (Please explain in comments)

Comment(s):____

4. Which of the following GCAS modes would you consider as beneficial? Select any or all of the answers that you think apply. If you feel mode(s) other than those listed is/are necessary, choose item (f) and specify in the comments section.

(a) Approach/Landing
(b) Low Level
(c) Rapid Descent
(d) Takeoff
(e) Wind Sheer
(f) Other (Please specify)

Comment(s):____

____

____

5. Given the existence of different GCAS modes, please prioritize the following modes from most beneficial to least beneficial in the comments section? If you feel another mode is necessary, choose item (other) and specify what mode and why. (e.g. Approach/Landing 1, Low Level 2, Rapid Descent 3, Takeoff 4, Wind Sheer 5, Other (Over Water--because . . .) 6).

Approach/Landing
Low Level
Rapid Descent
Takeoff
Wind Sheer
Other (Please specify)

Comment(s):____

____

____

6. Should the pilot be able to turn off the GCAS?

(a) Yes
(b) No
(c) Maybe

Comment(s):____

____

____

7. What should the pitch limits of the GCAS be?

Minimum (Lower) limit ________ Maximum (Upper) limit ________

Comment(s):____

8. What should the roll limits of the GCAS be?

Minimum (Lower) limit ________ Maximum (Upper) limit ________

Comment(s):____

9. Should the GCAS extrapolate beyond the range of the radar altimeter?

(a) Yes
(b) No

Comment(s):____

10. What should the maximum altitude coverage of the GCAS be?

(a) Maximum coverage of the radar altitude.
(b) 5000 feet
(c) 10,000 feet
(d) Maximum altitude (ceiling) of the aircraft.

Comment(s):____

11. What should the GCAS minimum descent altitude (altitude where the GCAS warning is inhibited) be?

(a) 0 feet
(b) 50 feet
(c) 100 feet
(d) 200 feet
(e) Other (please specify)

Comment(s):____

____

____

VISUAL MODE

1. What type of light would you consider to be most beneficial in alerting the aircrew of a possible ground collision?

(a) Flashing
(b) Steady
(c) Other (Please specify)

Comment(s):____

____

____

2. What nomenclature should be printed on the warning light?

(a) Altitude
(b) Climb
(c) GCAS
(d) Pull up
(e) Recover
(f) Other (Please specify)

Comment(s):____

____

____

3. How long should the warning light be present?

(a) 1 second (s)
(b) 2 s
(c) 3 s
(d) 4 s
(e) 5 s
(f) As long as the warning condition exists.
(g) Other (Please specify)

Comment(s):____

____

____

4. If a flashing light is chosen, what time interval between warnings would you consider optimal (e.g. light, 1 second interval, light)?

(a) .1 s
(b) .5 s
(c) 1.0 s
(d) Other (Please specify)

Comment(s):____

____

____

AUDITORY MODE

TONE WARNING

1. What type of tone would you consider to be most beneficial for alerting the aircrew of a possible ground collision?

(a) Intermittent
(b) Steady
(c) Wavering
(d) Alternating between steady and wavering tone
(e) Other (Please specify)

Comment(s):____

____

____

2. How long should each warning signal be present?

(a) 1 second (s)
(b) 2 s
(c) 3 s
(d) As long as the warning condition exists.
(e) Other (Please specify)

Comment(s):____

3. For an intermittent tone, what time interval between warnings would you consider optimal (e.g. tone, 1 second interval with no tone, tone)?

(a) .1 s
(b) .5 s
(c) 1.0 s
(d) Other (Please specify)

Comment(s):____

VOICE WARNING

1. What type of voice should it be?

(a) Computerized female
(b) Computerized male
(c) Human female
(d) Human male
(e) Other (Please specify)

Comment(s):____

2. What voice message would you consider to be most effective in alerting the aircrew of a possible ground collision?

(a) Altitude
(b) Climb
(c) Pull up
(d) Recover
(e) A combination of two or more messages listed above (Please specify)
(f) Other (Please specify)

Comment(s):____

3. How many times should the voice warning be presented?

(a) One (e.g. altitude)
(b) Two (e.g. climb, climb)
(c) Three (e.g. pull up, pull up, pull up)
(d) Until the conditions to affect recovery are completed.
(e) Other (Please specify)

Comment(s):____

4. What time interval between warnings would you consider optimal (ex: "Recover", 1 second interval, "Recover")?

(a) .1 s
(b) .5 s
(c) 1.0 s
(d) Other (Please specify)

Comment(s):____

MINIMUM ACCEPTABLE CLEARANCE ALTITUDE

The Minimum Acceptable Clearance Altitude (MACA) graph is on the following page. This graph represents the relationship between what a pilot feels is the minimum acceptable clearance altitude (Above Ground Level-AGL) given the aircraft's downward vertical velocity (Vz). MACA is the lowest altitude (AGL) that an aircraft reaches during recovery from the initial GCAS warning for which a pilot feels minimum stress. For example, if the alarm sounds with a Vz of 600 feet per minute (fpm), the minimum acceptable clearance altitude for a given pilot might be 150 feet (AGL), whereas, at a Vz of 6000 fpm, it might be 1000 feet. (This is only an example, the numbers do not reflect any sort of experimentally collected data.) We would like you to draw a line that best approximates your minimum acceptable clearance altitudes for the given downward vertical velocity onto the graph. Please give this careful consideration and take enough time in drawing the line. Please draw directly on the graph and answer the following question.

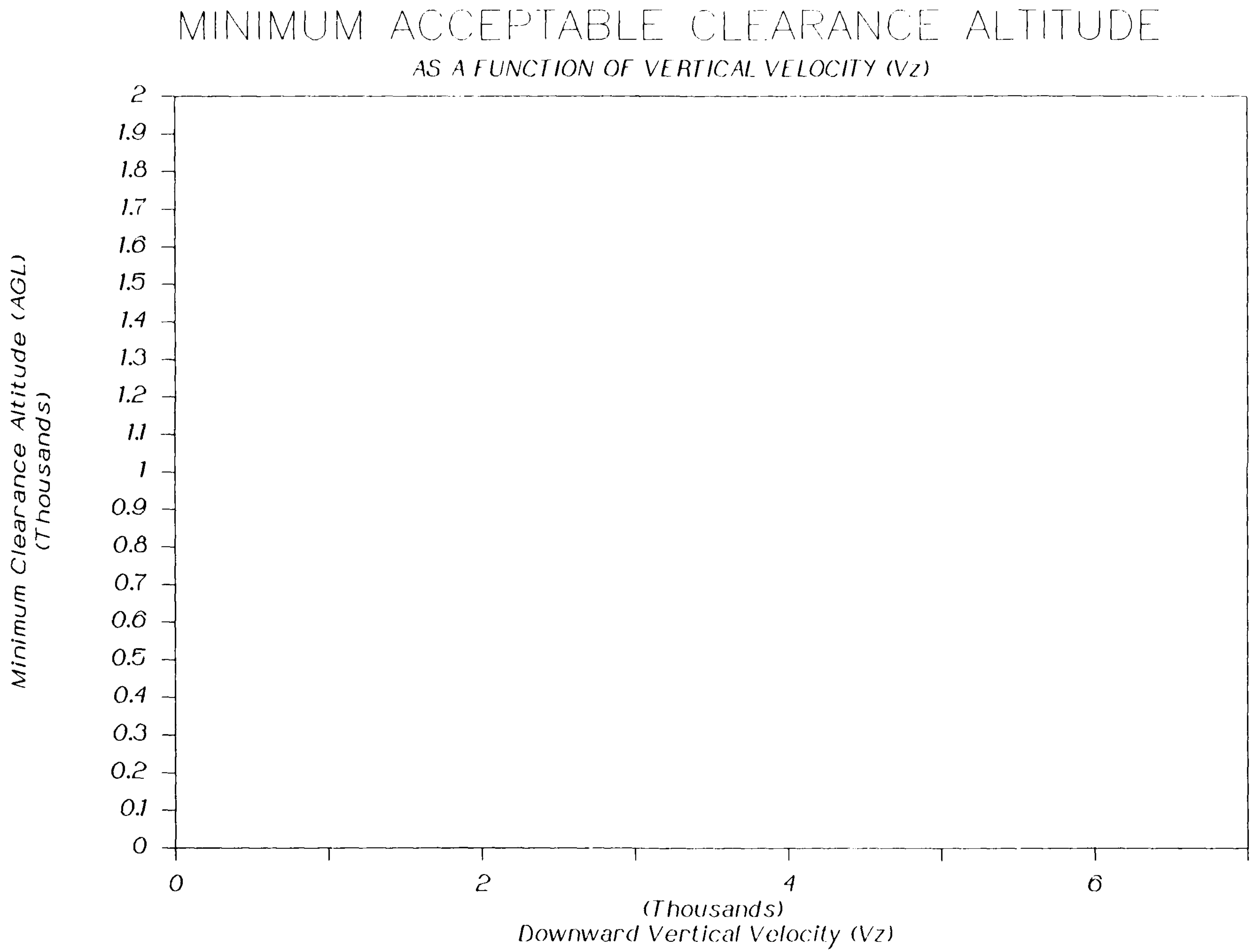
1. Do you fully understand what the minimum acceptable clearance altitude is and how to draw it onto the graph?

(a) I fully understand what MACA is and how to plot it.
(b) I fully understand what MACA is but am uncertain how to plot it.
(c) I do not understand what MACA is and am uncertain how to plot it.
(d) Other (Please specify)

Comment(s):____

____

____


MINIMUM ACCEPTABLE CLEARANCE ALTITUDE
AS A FUNCTION OF VERTICAL VELOCITY (Vz)
Minimum Clearance Altitude (AGL)
(Thousands)
2
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
2
4
6
(Thousands)
Downward Vertical Velocity (Vz)